Figure 1: Delay-and-Weight Beamforming

$$L \Rightarrow \quad OPL = n*L$$

$$n$$

$$\begin{cases} \Delta OPL = \Delta n * L \\ \Delta OPL = n*\Delta L \end{cases}$$

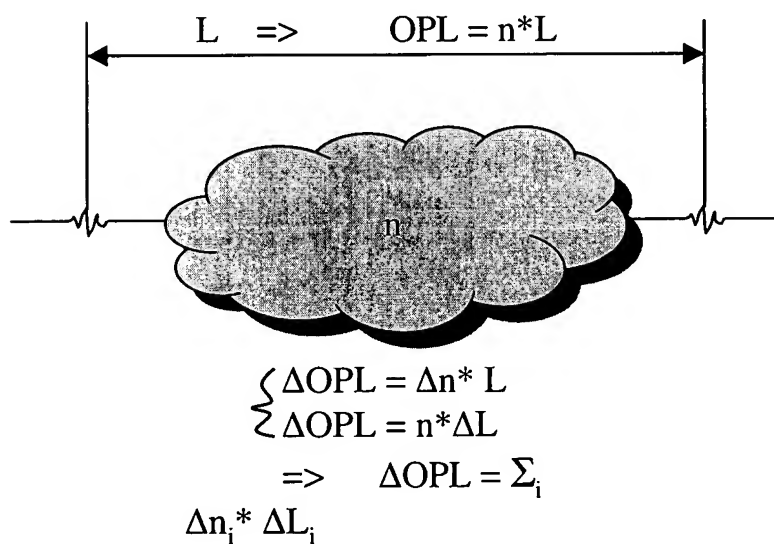$$\Rightarrow \quad \Delta OPL = \Sigma_i$$

$$\Delta n_i * \Delta L_i$$

Figure 2. Optical path length (OPL) and its variation

Figure 3A: Continuously Variable Optical Delay
(Prior Art)

Figure 3B: Continuously Variable Optical Delay
with folded optical paths
(Prior Art)
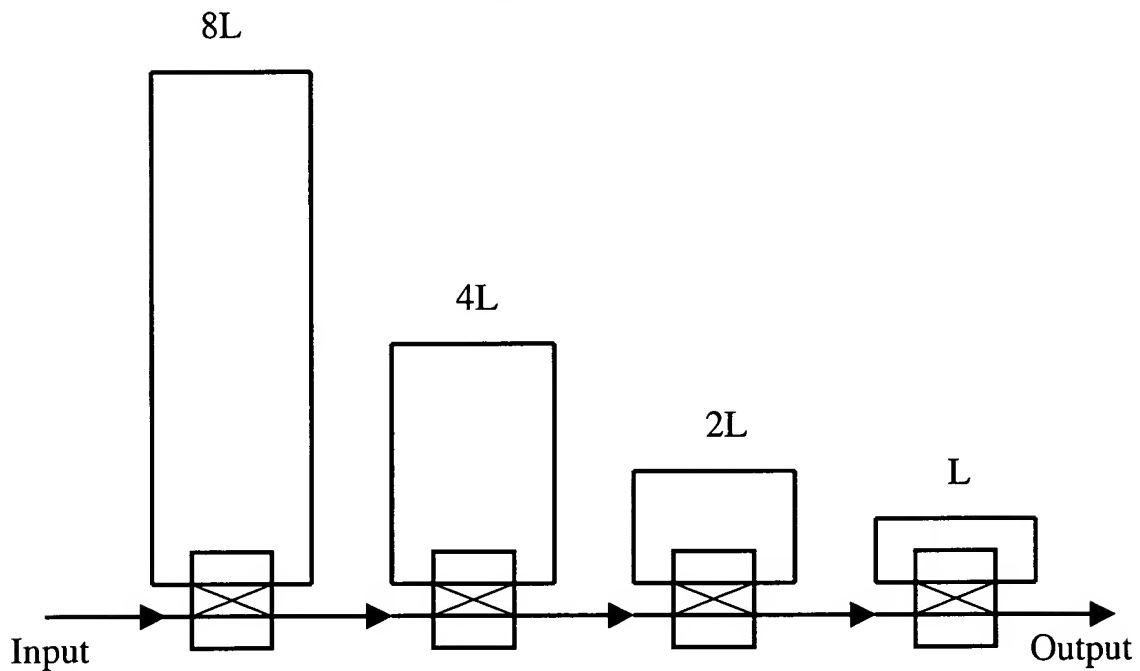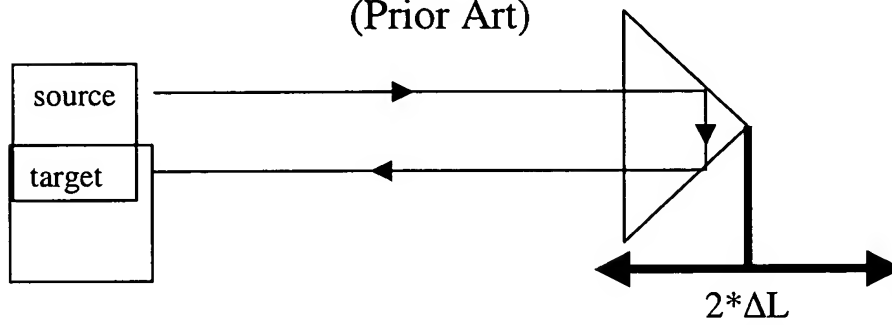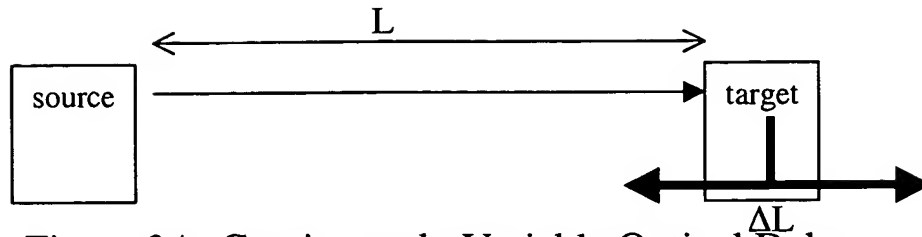

Figure 4: Discretely Variable Optical Delay using Optical Manifolds
(Prior Art)

L

512

Fig 5A: V = 0 $\Rightarrow n = n_0$

512 510

Fig 5B: $0 < V < V\_max$ $\Rightarrow n = n_0 + \alpha * \Delta n$
with $0 < \alpha < 1$

Fig 5C: $V = V\_max$ $\Rightarrow n = n_0 + \Delta n$
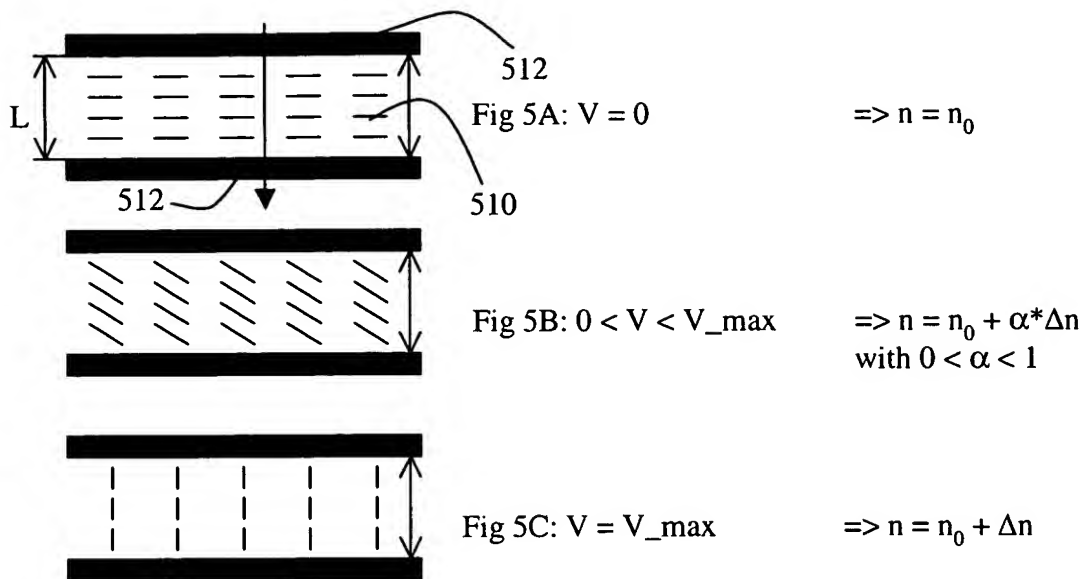
Dynamically variable optical delay: $\Delta OPL = \alpha * \Delta n * L$

Figure 5

(1/n) L 620

(1/n) 622
2*L

$\Delta OPL\_max = \Sigma_i \, \Delta n_i * L_i$
$= (n-1)*(1+2+4 \dots 2^n)*L$

$\Delta OPL\_min = 0$

624

(1/n) $2^n * L$

Air/Liquid injection
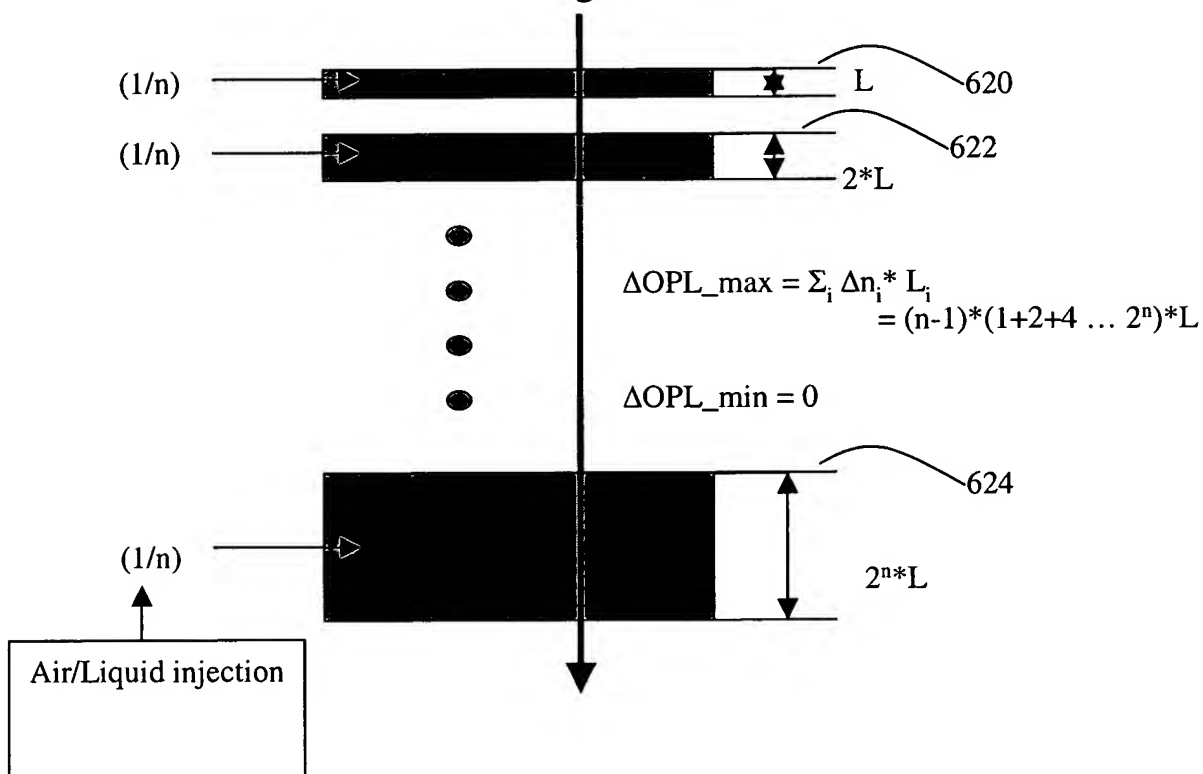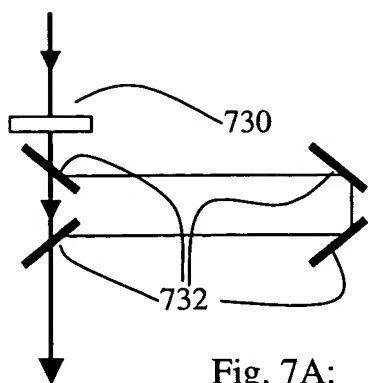
Figure 6

Fig. 7A:
Pass-through path

Fig. 7B:
Folded path

Polarizing Beam Splitter (passive) 732

Input

LC Polarization Rotator (active) 730

P-polarized

S-polarized
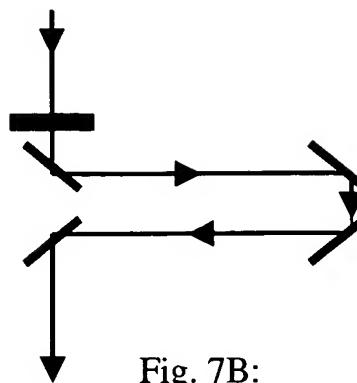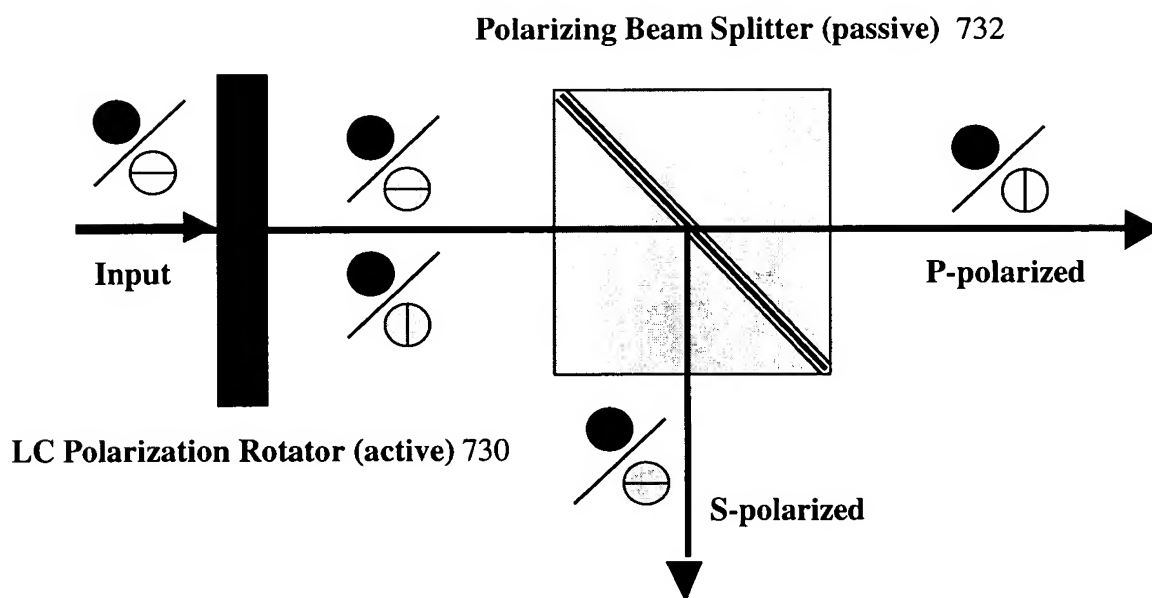
Fig. 7C: LC polarization optical switch

PS

TIR or 100% Transmission

844

842

846

2^{n-1}

840

2^{n-2}
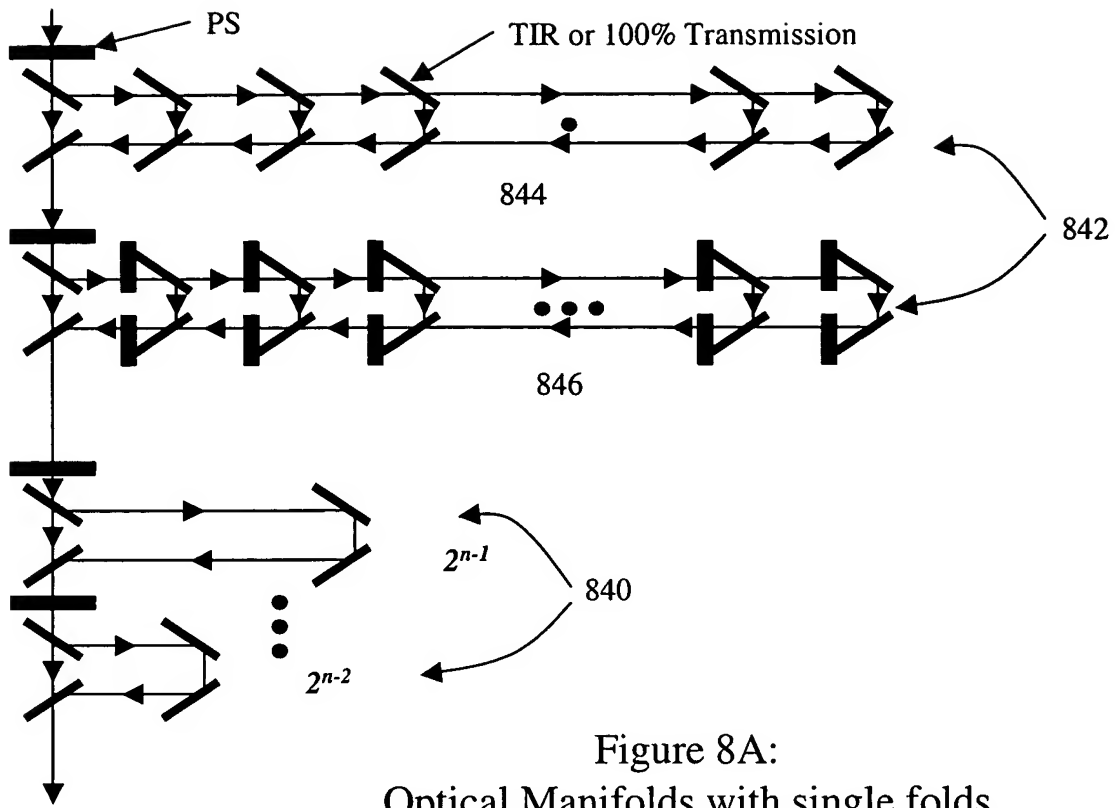
Figure 8A:
Optical Manifolds with single folds
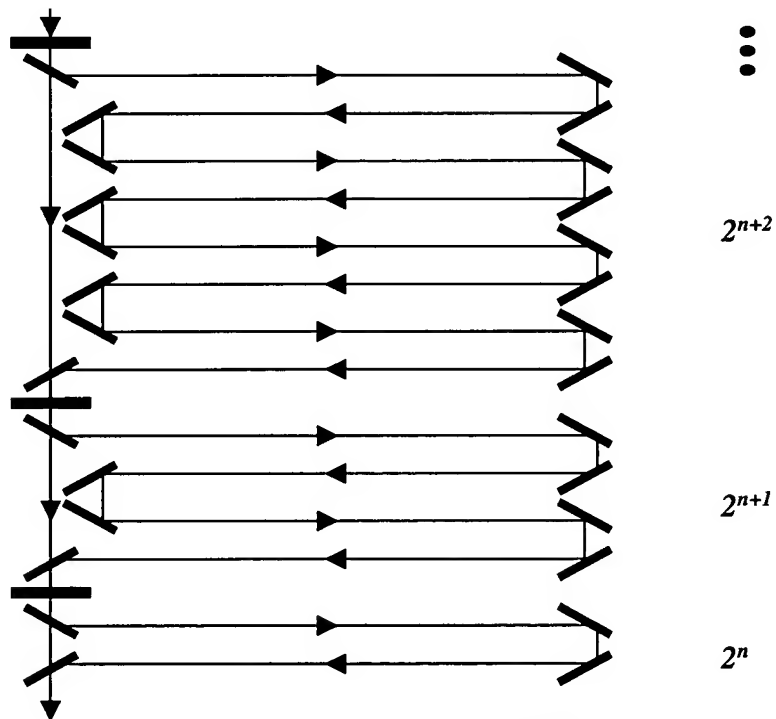
2^{n+2}

2^{n+1}

2^{n}
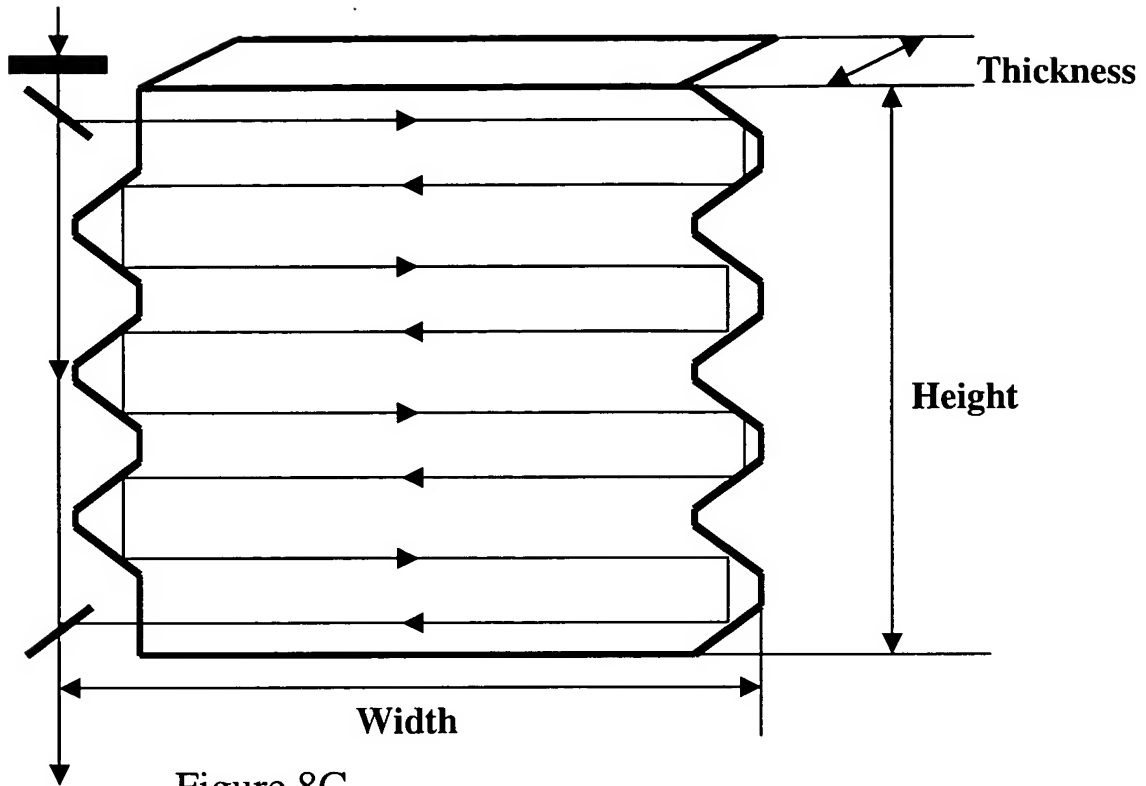
Figure 8B
Optical manifolds with multiple folds

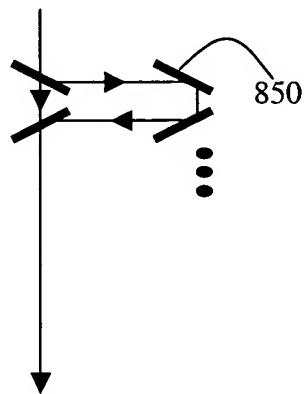Figure 8C
Molded optical manifolds

Figure 8D: Micro-Fluidic Variable Optical Delays

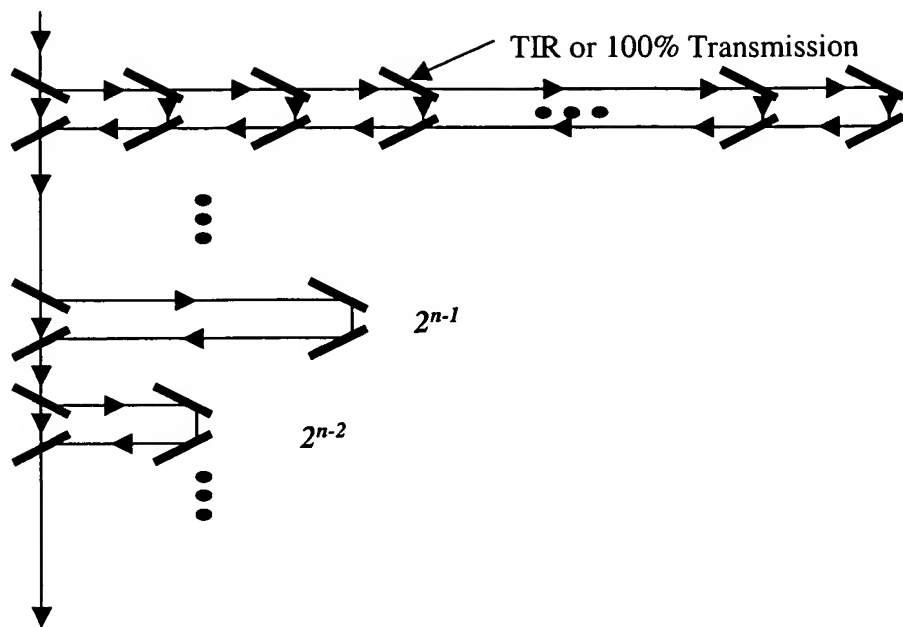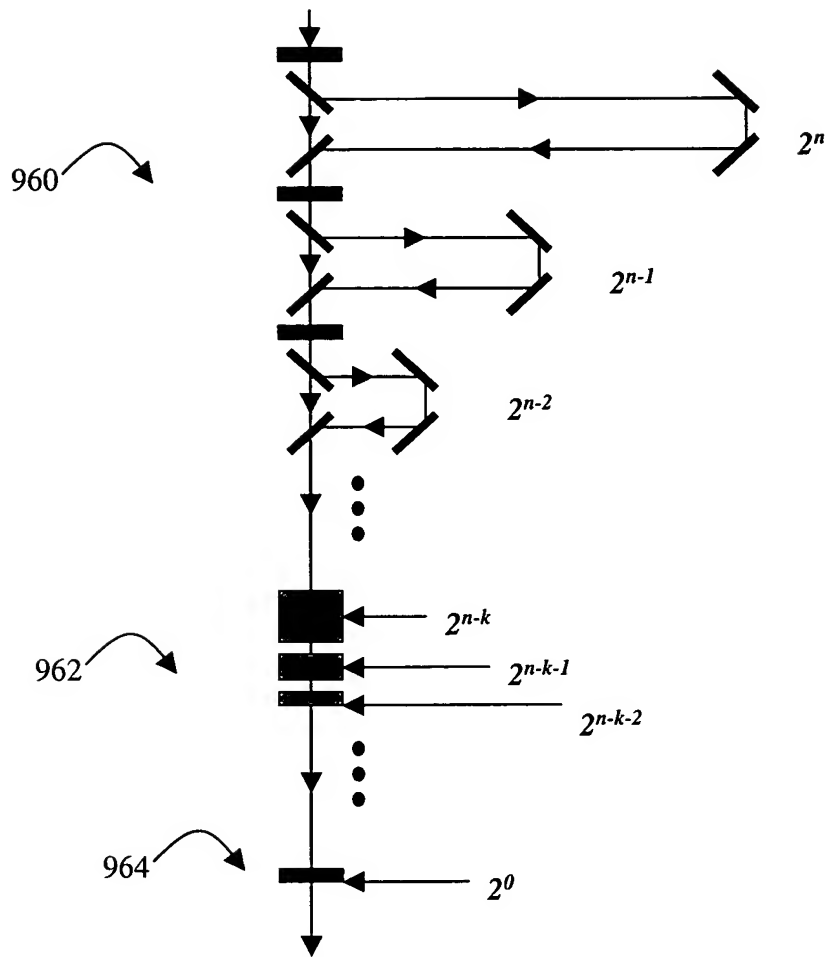Figure 8E: Micro-Fluidic Optical Manifolds
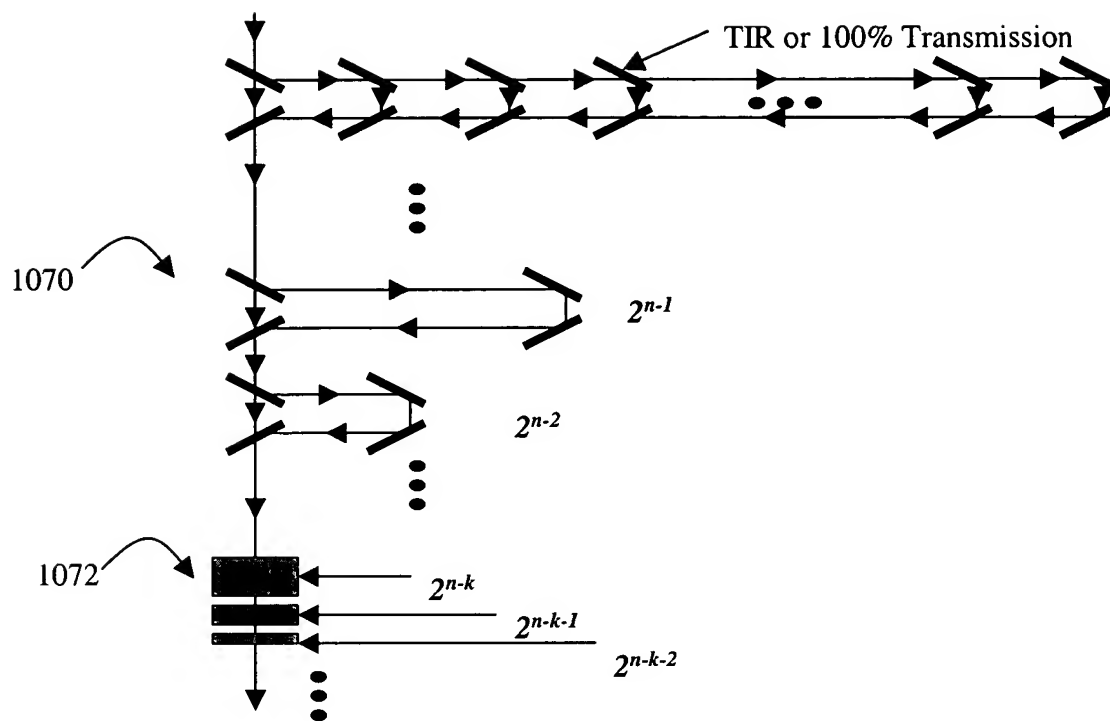
Figure 9: VOD with Coarse and Fine Delays

TIR or 100% Transmission

1070

2^{n-1}

2^{n-2}

1072

2^{n-k}

2^{n-k-1}

2^{n-k-2}

Figure 10: All-Micro-Fluidic Variable Optical Delays

BE   LCS   PBS / Mirror   FR   WP   LP   LCV   BE
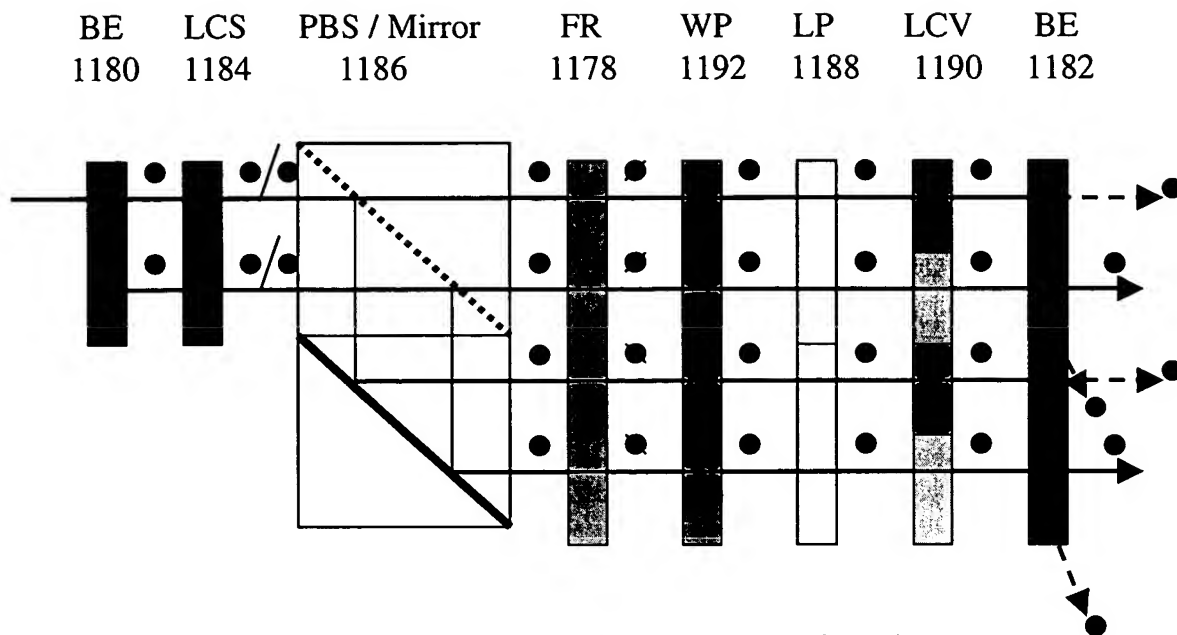1180   1184   1186   1178   1192   1188   1190   1182

Figure 11A: Optically Isolated
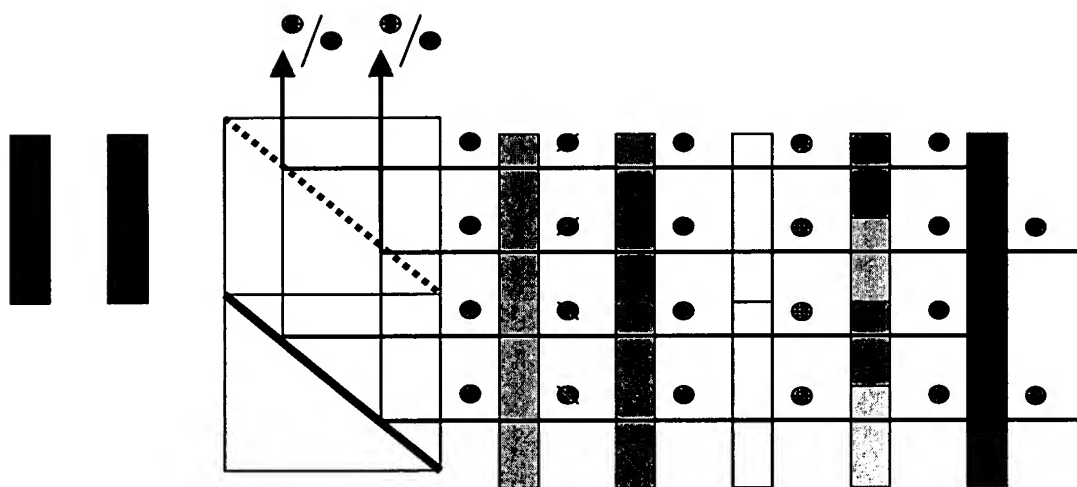VOA and 1x2 Optical Switch-
Forward Propagation

Figure 11B: Optically Isolated
VOA and 1x2 Optical Switch-
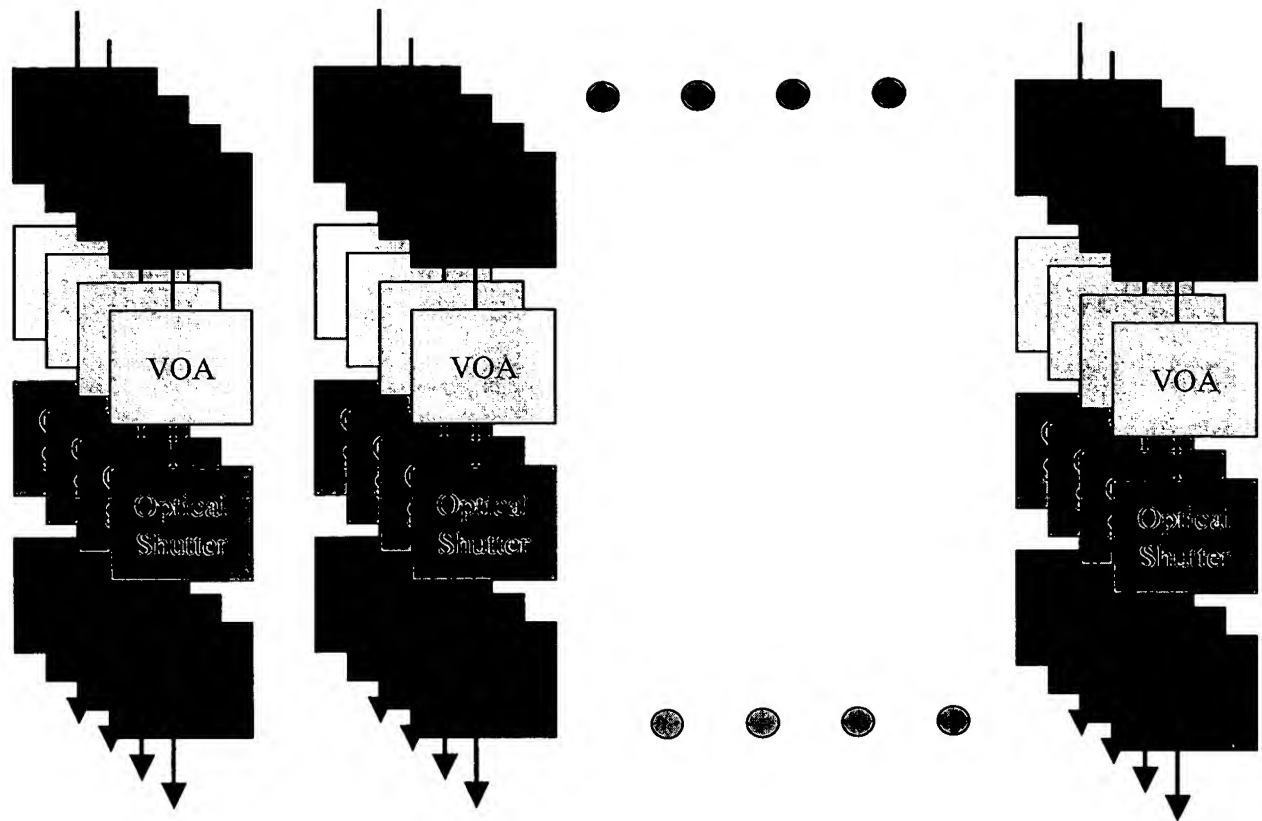Backward Propagation

Figure 12: Massively-Parallel Analog
Optical Processing Module Using Arrayed VOD